World City Formation and Long-Distance Communication under Conditions of Contemporary Globalization: An Empirical Investigation of the Relationship between Air Traffic and Global Service Connectivity[1]

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Abstract

This paper investigates the relationship between world city formation – as measured through global connectivities produced by advanced producer service firms – and global air transport flows. Firstly, we examine the obstacles related to the construction of careful measurements of (i) a city's global airline connectivity, and (ii) its economic importance in the context of a globalized economy, and use this as a starting point to show how recent advances in conceptual and empirical research on global cities have been able to tackle some of these problems. This has allowed social scientists to construct extensive global measurements of the importance of cities in terms of air transport and corporate development. The second section of the paper compares these two sets of measurements through a simple statistical technique (standard least squares regression analysis). Through an examination of the regression residuals, this analysis allows the investigation of differences in importance between a city's global air linkages and its corporate development. We interpret the results in terms of cities being under-developed and/or over-visited or being over-developed and/or under-visited. The end-result is a systematic analysis of the multifaceted relation between air travel and world city development under conditions of contemporary globalization.

INTRODUCTION

This paper aims to contribute to the literature that attempts to measure the dynamics of globalization, of which the rise of a 'world city network' has been one of the key identifiers. Through the 1990s one particular criticism of this world city literature became commonplace: there was a severe empirical deficit as regards inter-city relations.[2] That this could be fundamentally debilitating was abundantly clear, since the raison d'être of these cities is

[1] An earlier version of this paper has been published as P. J. Taylor, B. Derudder, F. Witlox, *Comparing Airline Passenger Destinations with Global Service Connectivities: A Worldwide Empirical Study of 214 Cities*, in "Urban Geography" 28 (2007), pp. 232-248. We would like to thank Bob Lake and one of the anonymous referees for their useful comments on an earlier draft of this paper. This research has, in part, been funded by the Scientific Research Fund-Flanders, Research Project G.0214.04.

[2] E.g. P. L. Knox, *World cities and the organization of global space*, in *Geographies of Global Change*, ed. R. J. Johnston, P. J. Taylor, M. J. Watts, Oxford 1995, pp. 232-248; D. A. Smith, M. Timberlake, *Cities in global matrices: toward mapping the world-system's city-system*, in *World Cities in a World-System*, ed. P.L. Knox, P. J. Taylor, Cambridge 1995, pp. 79-97; Id., *Conceptualising and mapping the structure of the world system's city system*, in "Urban Studies" 32 (1995), pp. 287-302; P. J. Taylor, *Hierarchical tendencies amongst world cities: a global research proposal*, in "Cities: The International Journal of Urban Policy and Planning" 14 (1997), pp. 323-332; Id., *So-called "world cities": the evidential structure within a literature*, in "Environment and Planning A" 31 (1999), pp. 1901-1904; Id., *World cities and territorial states under conditions of contemporary globalization*, in "Political Geography" 19 (2000), pp. 5-32; J. V. Beaverstock, R. G. Smith, P. J. Taylor, *World city network: a new metageography?*, in "Annals of the Association of American Geographers" 90 (2000), pp. 123-134; J. V. Beaverstock, R. G. Smith, P. J. Taylor, D. R. F. Walker, H. Lorimer, *Globalization and world cities: some measurement methodologies*, in "Applied Geography" 20 (2000), pp. 43-63.

exactly their worldwide interconnections. But this potential evidential crisis has been averted in recent years. Two separate and distinctive solutions to the problem have been developed[3]: analysing the worldwide networks of corporate organisations[4], and describing the infrastructure that has enabled these organisations to go global[5]. It is the purpose of this paper to compare these two solutions by focusing on the most frequent manifestations of each approach, notably the organization of advanced producer service firms and the distribution of commercial airline traffic. We develop a basic quantitative evaluation of the relation between results of these two approaches and explore some of the empirical specifics that emerge from this analysis.

World city development is a result of the growing intensity of global flows of people, ideas, capital, etc., connecting cities across the world. However, the existence of transnational linkages between cities is not restricted to our present-day globalized society. Long-distance contacts and communications between cities are perhaps as old as urban societies themselves, and they have played a crucial role in urban development in the present as well as in the past. Moreover, the spatial structure of the current world city network is not only the outcome of present-day globalization but also of historical processes going back much further in time. As a result, continuity plays a significant role in the geography of city networks (strong links can still be observed, for example, between the cities of the old British Commonwealth)[6]. Although this paper investigates the specific relationship between urban development and global communication under conditions of contemporary globalization, we do not deny the existence of such a relationship in the past. On the contrary, we assume that the presence of large-scale city networks is a generic characteristic of urban societies.[7]

The paper starts with descriptions of the data and measures that we are comparing: firstly, network connectivities derived from office networks of service firms, and secondly, airline passenger flows. Next, we expound our quantitative methodology, before presenting our results in which cities are interpreted as being either under-served and/or over-visited or over-serviced and/or under-visited. In the conclusion we refer to the multiple faces of globalization.

MEASURING SERVICE CONNECTIVITIES FOR CITIES IN 2000

The choice of using advanced producer service firms (banks, insurance companies, accountancy firms, law and management consultancy firms, etc) and their office networks for the measurement of the world city network in the corporate organisation approach is partly a result of theoretical reasons, deriving from Saskia Sassen's identification of the 'global city'[8]. Sassen explicitly identifies leading financial and business service firms as critical to global

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[3] B. Derudder, *On conceptual confusion in empirical analyses of a transnational urban network*, in "Urban Studies" 43 (2006), pp. 2027-2046.
[4] E.g. B. J. Godfrey, Y. Zhou, *Ranking world cities: multinational corporations and the global urban hierarchy*, in "Urban Geography" 20 (1999), pp. 268-281.
[5] E.g. S. Graham, *Global grids of glass*, in "Urban Studies", 36 (1999), pp. 929-949.
[6] P. J. Taylor, *World City Network: A Global Urban Analysis*, London 2004.
[7] P. J. Taylor, M. Hoyler, R. Verbruggen, *External Urban Relational Process: Introducing Central Flow Theory to Complement Central Place Theory*, 2008 (GaWC Research Bulletin 261) (http://www.lboro.ac.uk/gawc/rb/rb261.html); R. Verbruggen, *The External Relations of Cities in the Low Countries: A Geographical Appreciation of Historical Research on Urban Networks*, 2008 (GaWC Research Bulletin 272) (http://www.lboro.ac.uk/gawc/rb/rb272.html).
[8] S. Sassen, *The Global City: New York, London, Tokyo*. Princeton 1991 (2nd edition 2001).

city formation. Using this argument, GaWC research[9] has analysed the office networks of such firms across cities to describe a 'world city network'.[10] Sassen also suggested that it is "the nature of the production process in advanced industries, whether they operate globally or nationally, that has contributed to the immense rise in business travel in all advanced economies over the past decade, the new electronic era".[11] In this paper, we will assess to what degree this statement is supported empirically.

The employed measures for assessing connectivity in a network of global service centres are based upon a specification of a 'world city network'[12] and a consequent data collection[13]. Here we summarise this work so that the network connectivities of cities as input to our model can be understood, but for details and justifications, reference should be made to the original sources.

We postulate a world city network that is created by advanced producer service firms in the everyday operation of their activities. These activities require a network of offices in cities across the world for carrying out large transnational projects (e.g. inter-jurisdictional law, global advertising programmes). In this way, intra-firm movements between offices of information, knowledge, plans, instructions, personnel, etc. 'inter-lock' cities, producing and reproducing a world city network. Thus cities are connected to other cities through the offices of their resident advanced producer service firms. In order to measure how inter-connected a city is within the network, we therefore need to study the office networks of firms.

Advanced producer service firms have different strategies in their use of cities across the world. We define v_{ij} as the service value of city i for firm j. It can be thought of as the importance of the city within the firm's office network. The surmise is: the more important the office, the more intra-firm flows will be generated. Thus, the estimated flow or connection between two cities a and b (c_{ab}) is given by:

$$c_{ab}= \sum_j v_{aj}\, v_{bj} \qquad [1]$$

[9] GaWC or the Globalization and World Cities Research Network, see http://www.lboro.ac.uk/gawc.

[10] P. J. Taylor, G. Catalano, N. Gane, *A geography of global change: cities and services, 2000-01*, in "Urban Geography" 24 (2003), pp. 431-441; P. J. Taylor, *World City Network.*

[11] S. Sassen, *Globalization and Its Discontents*. New York 1998, p. 397. The hypothesis that the dramatic increase of ICT-enabled business practices actually boasts corporeal travel and associated face-to-face contacts has recently been supported by J. M. Denstadli, *Impacts of videoconferencing on business travel: the Norwegian experience*, in "Journal of Air Transport Management" 10 (2004), pp. 371-376. Denstadli's analysis suggests, for instance, that videoconferencing goes hand in hand with business air travel, with substitution rates as low as 2.5–3.5%. Thus ICT-practices pose no serious threat to the airline industry, and should be regarded as supplementary to personal contact. However, this does not imply that there is a direct parallel between the geographic structure of, say, the Internet backbone and air transport networks: J. H. Choi, G. A. Barnett, B. S. Chon, *Comparing world city networks: a network analysis of Internet backbone and air transport intercity linkages*, in "Global Networks" 6 (2006), pp. 81-99, for instance, have shown that both 'spaces of flows' are similar, but by no means exact copies. Both structures exhibit strong inter-linkages between North American and European cities, and feature the London–New York dyad as the strongest linkage in the global flow of information and people. But differences between the two networks do exist. For instance, Asian cities have lower positions in the Internet network than in the air transportation network, which reflects a relatively weak deployment of inter- and intra-regional Internet backbone connections.

[12] P. J. Taylor, *Specification of the world city network*, in "Geographical Analysis" 33 (2001), pp. 181-194.

[13] Described in P. J. Taylor, G. Catalano, D. R. F. Walker, *Measurement of the world city network*, in "Urban Studies" 39 (2002), pp. 2367-2376.

The sum of all such inter-city connectivities for a given city provides the measure for its network connectivity:

$$C_a = \sum_i c_{ai} \qquad [2]$$

To operationalise the measurement, data are required on the offices of advanced producer service firms in cities across the world. In 2000 data were collected on the offices of 100 advanced producer service firms (the "GaWC 100": 18 in accountancy, 17 in advertising, 23 in banking/finance, 11 in insurance, 16 in law, and 15 in management consultancy) for 315 cities. Firms were chosen to be global: they had to have offices in at least 15 different cities that had to include at least one from each of northern America, western Europe and Pacific Asia. Cities were chosen from experience with working on cities to ensure all important service centres across the world were included. From information on the firms gathered from their websites, service values were allocated to each city on a range from 0 (no presence) to 5 (headquarter location). This produced a service value matrix of 100 firms x 315 cities. It is from these 31,500 pieces of information that global service network connectivities were computed using equations [1] and [2]. The higher the connectivity score C, the more connected a city is through its service firms in the network. Connectivities ranged from 63354 and 61859 for London and New York respectively to two cities with zero, Lucknow and Pyonyang (i.e. none of the GaWC 100 had offices located in these two cities). It are these connectivity values that are the first input for the model below.

UNIQUE DATA ON AIRLINE PASSENGER FLOWS FOR 2001

The use of standard air travel statistics as the common 'data of choice' for researching worldwide inter-city relations has been largely a data-led decision since information on international flows is publicly available.[14] In addition, however, these data with their description of flows between city airports have been popular because they provide concrete manifestations of inter-city flows that are relatively easy to analyse and interpret. The main problem with standard data sources on air traffic is that they detail international rather than global flows (thus 'downgrading' New York with its numerous domestic flights) and that they take the hub function of airports into account (thus 'upgrading' London with its numerous (non-domestic) onward connection flights).

We overcome these problems by using a unique data set (for social science research) that provides information on individual passenger flows in 2001. This so-called 'MIDT-database' is described in detail in previous articles by Derudder and colleagues,[15] and reference should be made to these publications for further details. Here we produce a summary so that the input to our model can be understood.

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[14] D. J. Keeling, *Transport and the world city paradigm*, in *World Cities in a World-System*, ed. P. L. Knox, P. J. Taylor, Cambridge 1995, pp. 115–131.
[15] B. Derudder, F. Witlox, *An appraisal of the use of airline data in assessing the world city network: a research note on data*, in "Urban Studies" 42 (2005), pp. 2371-2388; B. Derudder, F. Witlox, P. J. Taylor, *United States cities in the world city network: comparing their positions using global origins and destinations of airline passengers*, in "Urban Geography" 28 (2007), pp. 74-91; B. Derudder, L. Devriendt, F. Witlox, *Flying where you don't want to go: an empirical analysis of hubs in the global airline network*, in "Tijdschrift voor Economische en Sociale Geografie" 98 (2007), pp. 307-324.

The MIDT database contains information on bookings made through so-called Global Distribution Systems (GDS) such as Galileo, Sabre, Worldspan, Topas, Infini and Abaccus.[16] GDS (or Computer Reservation Systems (CRSs))[17] are electronic platforms used by travel agencies to manage airline bookings (i.e. the selling of seats on flights offered by different airlines), hotel reservations, and car rentals. Using a GDS-based database therefore implies that bookings made directly with an airline are excluded from the system and therefore from the data. However, in 1999 80% of all reservations continued to be made through GDS.[18] Thus, although our information source may give a slightly biased picture of airline connections, there is no reason to assume that the overall pattern of reservations made by direct bookings differs fundamentally from that for reservations made through a GDS.

The main reason for choosing this MIDT database over standard data sources is that it has several advantages in the context of world city network research.[19] Firstly, as the MIDT-database contains real origin/destination information of passengers, the overrating of the connectivity of airline hubs and first-tier world cities is minimized, which allows assessing the relational patterns in the lower rungs of the world city network in more detail (e.g. the downsizing of the importance of hub cities such as Amsterdam and Frankfurt). Secondly, the MIDT-based database does not distinguish between national and international flows, and can therefore be thought of as a truly global intercity matrix. The New York–Chicago link is appropriately treated in the same way as the New York–Toronto link, for example. This further reduces the underestimation of second-tier cities in large and/or significant nation-states.

The main problem with this data source is that it remains largely impossible to discern world city business flows from other flows. The importance of the New York–Miami route and particularly the New York–Las Vegas route, for instance, suggests more than a business link. Linkages related to obvious holiday destinations such as Palma de Mallorca were deleted from the database (see below), but this manipulation only works for airports that are obviously not world-city airports. Furthermore, although the availability of global origin/destination data addresses the undervaluation of second-tier world cities, airline data cannot avoid undervaluing a second-tier city that is located closely to a major world city. For example, a passenger travelling from Rotterdam to New York is likely to depart from Amsterdam because of (i) the short distance between Rotterdam and Amsterdam (less than 50 miles) and (ii) the importance of Amsterdam's Schiphol airport. These limitations will be identified in our analyses below.

With the cooperation of an airline company, we were able to obtain a partial MIDT database that covers the period from January to August 2001 and contains information on more than 500 million passenger movements. This database has been used to construct a global intercity matrix detailing the total volume of passenger flows between cities. To achieve this, we relabelled the airport codes as city codes. This was necessary to compute meaningful intercity measures, because a number of cities have more than one major airport. The particular airport used by a passenger is not important in this context because, for recording the London–New York relation, it is irrelevant whether a flight goes from Heathrow to JFK or from Gatwick to Newark. Having summed the directional information into a single measurement detailing the

[16] Shepherd Business Intelligence, 2005 (http://www.shepsys.com).
[17] The first CRS (i.e. Sabre) was developed in order to help American Airlines with their (manual) booking system. CRSs became a key weapon in the newly competitive airline industry.
[18] W. H. Miller, *Airlines take to the internet*, in "Industry Week" 248 (1999), pp. 130–134.
[19] See B. Derudder, F. Witlox, *An appraisal*.

total volume of passengers, we created a global intercity matrix that focuses on the most important cities in the world economy. For this, we used the city list compiled by GaWC for the global services research detailed above. Nine of these 315 cities were excluded either because they had no airport (e.g. Bonn and Kawasaki) or because the airport was not serviced in the period under consideration because of political instability (e.g. Kabul). This reconfiguration produced a 306 × 306 matrix that quantifies the passenger flows between important cities in the world economy. This provides the second input into the model, a direct measure of infra-structure flows.

METHODOLOGY: REGRESSION RESIDUAL ANALYSIS

The first decision to be made for analysis was to make a further selection of cities for investigation. Within the GaWC data matrix many of the 315 cities have relatively few offices of the selected advanced producer service firms, so that their connectivity measures are not necessarily robust: the veracity of the measure of connectivity and related analyses depend upon using large numbers of firms so that they are not dependent upon a few particular firms in a city. Thus published analyses of these data have used less than 315 cities, with different exclusion rules depending on the analysis, i.e. 62 cities[20], 123 cities[21], and 234 cities[22]. Combining the two data sets, we produced thresholds that avoided low values for either variable: to be included cities had to have connectivities above 10% of the most connected city (i.e. London) and have serviced more than 100,000 passengers in the period under investigation. This produced a worldwide roster of 214 cities.

The second decision to be made was to choose the method for analysing the relationship between both measures. The basic technique for exploring the relation between variables is a standard least squares regression analysis. This method uses a simple bivariate function. Hereby, we treat the passenger totals as the dependent variable, since – according to Sassen – it is the service function of cities that generates airline passengers. Obviously only some passengers specifically will have been travelling for the purpose of one of the selected advanced producer service firms, the vast majority will not, so that we are using global service connectivity as both a specific variable and as a surrogate for general business activity in a city – this distinction will be fundamental for interpreting the results. The following equation was used to describe the relationship:

$$P = \alpha \pm \beta\, C \pm \varepsilon \qquad [3]$$

where P is the total number of passengers, C is a city's global service connectivity (from equation [2]), α is the estimated intercept of the P axis, β the estimated gradient (change in P for a one unit change in C), and ε is the residual, or error term, recording the difference between actual passengers and the number predicted by the equation for a given city.

Before proceeding, one more technical note needs to be made. The proper application of a standard linear regression presupposes 'homoskedasticity'. This means that it is necessary that

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[20] P. J. Taylor, *World City Network*; B. Derudder, P. J. Taylor, *The cliquishness of world cities*, in "Global Networks" 5 (2005), pp. 71–91.

[21] P. J. Taylor, G. Catalano, D. R. F. Walker, *Exploratory analysis of the world city network*, in "Urban Studies" 39 (2002), pp. 2377-2394.

[22] B. Derudder, P. J. Taylor, F. Witlox, G. Catalano, *Hierarchical tendencies and regional patterns in the world city network: a global urban analysis of 234 cities*, in "Regional Studies" 37 (2003), pp. 875–886.

the variance in both variables remains constant over the entire data range. This is clearly not the case here: the variance in both variables dramatically increases with greater values of both P and C, which implies that residuals cannot be interpreted properly. The classical solution to this 'heteroskedasticity' problem is to transform both variables by taking their logarithm, which aids in equalizing the variance over the entire data range. The actual values of P and C employed in equation [3] therefore pertain to the natural logarithms (ln) of both variables, ensuring that the prerequisites for a standard linear regression are met.

The initial calibration of equation [3] produced:

$$P = -1.49 + 1.66\ C \pm \varepsilon \qquad [4]$$

The estimate for the intercept α (-1.49) is a feature of the function chosen and since the intercept (where C = 0) is outside the data range, the estimated value of α is not of intrinsic empirical interest. The gradient β (1.66) shows that for every change of unit of business connectivity the unit of airline connectivity is increased by 1.66. The strength of this relationship is given by the correlation coefficient (r), which is 0.73, and the coefficient of determination (r^2), with a value of 0.53. The latter indicates that the connectivities account for just above 50% of the variability in passenger numbers across cities. This means that although both layers coincide significantly, there are some important differences in their respective geographies.

These differences can be studied through an assessment of the differences from the regression line (and therefore from the model). Rather than on statistical results of estimated coefficients, in this study our interest particularly focuses on the residuals. It is the latter that indicate the relative position of a city in the two processes being represented by the variables. The regression line of the equation is shown in Figure 1 on which the 214 cities are also plotted. By far the largest residual (vertical distance between a point and the regression line) is in the upper left of the diagram. The specific city represented by this point has many more visitors than its connectivity predicts – it has one of the lowest connectivities and yet is easily in the top quartile for numbers of visitors. The city is Las Vegas. Although not a major global service centre, it attracts huge numbers of visitors as a global tourist attraction. This example represents the largest error term in the model, because the premises of the model – that service connectivity on its own or as a surrogate for general business activity is responsible for the creation of all air travel to a city – least fit the reality of what attracts air passengers to Las Vegas.

Regression residual analysis is a very powerful tool for understanding processes, because it can identify which cases do not fit the model, thus indicating (as the Las Vegas example shows) alternative processes to be strongly operating. Accordingly, much of the reporting of results below focuses on the analysis of residuals. In the results the residuals are reported as standardised measures (in units of their standard deviation from the mean) to aid interpretation. Basically, standardised residuals with values more than 1 or less than -1 suggest the possibility of processes outside the model being important, above 2 or less than -2 strongly suggest this and, above 3 or below -3 definitely indicate the operation of a process not in the model. The largest residual value in our model is found for Las Vegas with an exceptional 3.24, indicating without doubt the existence of an alternative process. The Las Vegas case is clear-cut, which makes it a useful pedagogic example, but other large residuals are less obvious and attempting to interpret them is what makes residual analysis more useful and interesting.

RESULTS FROM A TWO MODEL ANALYSIS

The model specified in equation [4] above has a pedagogic use but it is not the relationship that constitutes the results of this study. On computing the residuals from this model it was found that the US cities values were very unevenly distributed. All US cities had positive residuals: they had more passengers than predicted, which indicates that US cities constitute a different population of cities in terms of the relationship we are modelling. The positive residuals could result from extra air travel amongst US cities or less global service connectivity, a feature of US cities previously reported by Taylor and Lang[23]. In reality it is almost certainly a combination of both US particularities. For this reason we have chosen to carry out two separate regression analyses, one for the 37 US cities in our roster and another for the remaining 177 cities.

The two models are illustrated in Figure 2, which shows the US regression line wholly above that for the rest of the world. These lines represent the following equations:

(i) for US cities

$$P = 2.04 + 1.39\ C \pm \varepsilon \qquad [5]$$

(ii) for non-US cities

$$P = -2.28 + 1.72\ C \pm \varepsilon \qquad [6]$$

Note from equations [5] and [6] that the gradient is smaller for US cities. This means that the rate of increase in connectivity generates a smaller increase in air passengers to US cities than to non-US cities, albeit that the regression line in the data range constantly remains much higher for US cities throughout the entire data range. Put in another way: the decline in passenger numbers from New York as connectivity decreases is smaller than from London, albeit not great enough for the regression lines to cross: the US model always predicts more passengers for a given level of connectivity (Figure 2), an artefact of the well-developed and deregulated airline market in the United States[24].

As we might expect, the coefficients measuring the strength of the relationship are also quite different. For the 37 US cities the correlation coefficient is a very high 0.85 producing a coefficient of determination of 0.73. This indicates that for the USA our model works extremely well; the premise that air passenger numbers can be predicted accurately by connectivity is validated. Of course, the 177 other cities cover a wider range of circumstances and would thus not be expected to have such a strong model relationship. This is the case: the correlation coefficient is 0.78 producing a coefficient of determination of 0.61. However, this is still a very good result and again validates the model in general terms.

RESIDUAL ANALYSIS I : THE USA MODEL

[23] P. J. Taylor, R. E. Lang, *U.S. Cities in the ' World City Network'*, Washington (DC) 2005.
[24] R. Doganis, *The Airline Business in the 21st Century*, London and New York 2001.

We will start with the US model since the results are easier to interpret. Given this extremely well-fitted model, residuals are small with only seven cities with residuals above/below ±1, only two of which are above/below ±2 (Table 1). As well as cities and their residuals, this table suggests basic reasons for the residuals. High residuals can result from the city being either over-visited or under-serviced (or a mixture of both). In Table 1 we have provisionally suggested which interpretation applies to each of the cities. For instance, the city with the largest residual is Las Vegas, which we discussed previously for the combined city model (equation [2]); in this US model the residual is somewhat smaller but still substantial. Honolulu and New Orleans are also clearly tourist destinations that are over-visited relative to their respective service provisions, while the other positive residual suggests a different process outside the model: Phoenix has been notorious for its lower-than-expected rate of services[25]. The negative residuals cover 4 eastern cities; the two in the north east are industrial cities that we posit to be under-visited; possibly the two south eastern cities are over-serviced (Charlotte through its banking and Richmond as state capital).

What of the leading US world cities? The seven outstanding top cities (as defined by connectivity)[26] all fit the model very well (residuals below/above ±0.25, except for Los Angeles) but they do provide interesting contrasts (Table 2). Only New York and Los Angeles have positive residuals and can both be interpreted as cities that are much more than global service centres, hence each in their own way being over-visited in this analysis. A negative residual for Washington DC is the surprise here, since as capital city it might be expected to be over-visited; however it appears that the quantity of services the political function attracts outweighs the visitors: we interpret the city as over-serviced. Other more 'specialised' service cities can be interpreted in the same way: San Francisco for its banking and Miami for its Latin American headquarters are both considered relatively 'over-serviced'. On the other hand, Chicago and Atlanta's negative residuals are more likely due to being under-visited (remember airline hub-ness is removed from the data). Of course, these interpretations may be contested, but the results do show the potential of residual analysis to throw up interesting questions.

RESIDUAL ANALYSIS II: THE REST OF THE WORLD MODEL

As the coefficients reported above imply, the non-US city model has a much larger proportion of reasonably high and low residuals: 70 of the 177 cities have residuals above/below ±1. Given that we have separated out the US cities, the question arises whether there are other regions that might be separated from this reduced world model. Table 3 has been constructed to consider this question. Remember that for the original model (equation [4]), all US cities had positive residuals; in Table 3 this range is represented by the first two columns. Clearly no other region has a distribution of residuals as biased as the US had for the initial model: all regions have a reasonable spread of positive and negative residual cities. Certainly differences between regions are not enough to require a further division of our roster and we will proceed with our non-US model.

There are 26 cities with positive residuals above and 34 cities with negative residuals below 1 (Table 4), which suggests the possibility of processes outside the model being important. The cities thus identified constitute a varied group, and different interpretations can be given for

[25] J. R. Short, *Black holes and loose connections in the global urban network*, in "The Professional Geographer" 56 (2004), pp. 295-302.
[26] See P. J. Taylor, R. E. Lang, *U.S. Cities*.

the various residuals. Some of the top cities are capital cities that may be over-visited for their political function and under-serviced because of more important global service centres nearby, for example Toronto for Ottawa and Milan for Rome. In the latter case, since Bologna and Turin both occur in this list, Milan's 'service shadow effect' extends beyond the country's capital. Other 'second cities' in the list that may be similarly afflicted are Manchester, Gothenburg and the classic case in service deficiency: Osaka[27]. The negative residual cities in Table 4 that suggest the possibility of processes outside the model being important are more easily interpreted. Hamilton (Bermuda) and Luxembourg City, for instance, are specialist financial centres that can be deemed over-serviced. Another interesting feature of the negative residuals is the appearance of many Eastern European cities. These can be considered to be over-serviced given the attraction of global service firms to post-Cold War Eastern Europe to take advantage of new economic policies, especially the selling of state assets. Cities such as Rotterdam and Antwerp, in turn, are clearly under-visited (through their airports) because both cities are within short railway journeys to alternative large international airports (Amsterdam and Brussels respectively). An important reason for some of the deviations from the model can therefore be traced back to the fact that airline connectivity does not always assess the connectivity of a single, central location. Rather, some airports are in practice serving city-regions that may consist of one or more major cities together with their hinterlands, thus underestimating the infrastructural connectivity of some secondary cities and overestimating the connectivity of their neighbouring, dominant world city.

Finally what of the leading non-US world cities? Table 5 shows the top ten non-US world cities as defined by service connectivity from the 'Global North' plus the top ten of the 'Global South'. Most show a good fit to the model but there are several moderate exceptions. London and Paris, like New York and Los Angeles before, are much more than global service centres; this is reflected in their sizeable positive residuals interpreted as their being over-visited. In contrast Tokyo's negative residual suggests it is over-serviced: participation in the Japanese economy still means going through a lot of government channels given a fairly regulated economy. This implies that location in Tokyo is crucial, and results in the city being over-serviced. The Global South cities also exhibit a good fit. The largest positive residual, Bangkok, can be interpreted as over-visited. The four cities with negative residuals are interpreted as over-serviced, albeit for different reasons: Kuala Lumpur and Jakarta are part of a world economic region that is heavily defined by banking and finance services[28]; Beijing and Shanghai are similar to Eastern European cities for attracting global firms to service their reformed economy.

CONCLUSION

In this paper we have taken the opportunity of comparing results from two unique data analyses that deal with connectivities between large numbers of cities in contemporary globalization. This has enabled us to provide some detail about how various cities fare in our model linking measures of inter-city business relations and inter-city communication infrastructure relations. This has produced two distinctive findings: firstly, the model we propose and calibrate does provide a relatively good description of the relationship between these two particular spaces of flows, and secondly, there are numerous explicable divergences from the model. We interpret these findings as three levels of complexity:

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[27] R. C. Hill, K. Fujita, *Osaka's Tokyo problem*, in "International Journal of Urban and Regional Research" 19 (1995), pp. 167-93.
[28] P. J. Taylor, *World City Network*.

- There is a general overall globalization structure. As a result, there are many significant overlaps in the cross-layer model.
- There are multiple globalizations in the various layers of the space of flows. These are the many different processes that constitute the overall structure. We incorporated just two such processes in our model.
- There are a myriad uses of cities in the multiple globalizations, these provide the many roles that cities can play as nodes in the space of flows. This is illustrated by the residual cities in our model.

We are only just beginning to appreciate the empirical complexity of this socially constructed mega-space.

TABLES

Table 1: High and low residual US cities.

High positive residuals		
City	Residuals	Under-serviced or over-visited
Las Vegas	3,118	over-visited
New Orleans	1,284	over-visited
Phoenix	1,278	under-serviced
Honolulu	1,095	over-visited
Low negative residuals		
City	Residuals	Over-serviced or under-visited
Rochester	-2,293	under-visited
Richmond	-1,994	over-serviced
Charlotte	-1,276	over-serviced
Buffalo	-1,153	under-visited

Table 2: Leading US world cities.

City	Residual	Serviced or visited reason?
New York	0,161	over-visited
Chicago	-0,262	under-visited
Los Angeles	0,782	over-visited
San Francisco	-0,090	over-serviced
Miami	-0,018	over-serviced
Atlanta	-0,025	under-visited
Washington, D.C	-0,070	over-serviced

Table 3: Frequencies of residuals by world regions.

Region	Res. > 1,00	1,00 > res. > 0	0 > res. > -1,00	- 1,00 > res.	Total
Europe	12	28	15	11	66
East Asia and the Pacific	2	7	5	2	16
Former Soviet Union/Central Asia	0	2	1	4	7
Latin America	5	11	8	4	28
Middle East North Africa (MENA)	2	9	2	2	15
Oceania	0	5	4	1	10
Other N. America*	1	5	1	2	9
South Asia	2	5	1	2	10
Sub-Saharan Africa	2	5	3	6	16
Total	26	77	40	34	177

* All but two are Canadian cities, whereby the two non-Canadian cities (Nassau on the Cayman Islands (res. = 0,239) and Hamilton on Bermuda (res. = -1,038) have low/negative residuals. Thus 5 of Canada's 7 cities are in the first two columns (exceptions are Ottawa (-0,954) and Montreal (-1,014)), which implies that Canadian cities may be more like US cities than the rest of the world.

Table 4: Extreme residual non-US cities.

High positive residuals			Low negative residuals	
City	Residual		City	Residual
Guadalajara	2,067		Antwerp	-3,655
Bologna	1,988		Rotterdam	-2,723
Hanover	1,681		Lusaka	-2,475
Rome	1,645		Almaty	-2,464
Salvador	1,587		Asuncion	-2,121
Manchester	1,564		Maputo	-1,975
Ottawa	1,487		Luxembourg	-1,749
Turin	1,480		Hamilton	-1,709
Riyadh	1,434		Windhoek	-1,679
Marseilles	1,380		Hobart	-1,663
Portland	1,314		Kampala	-1,655
Port Of Spain	1,302		Montevideo	-1,613
Gothenburg	1,282		Zagreb	-1,561
Paris	1,275		Harare	-1,536
Osaka	1,255		Abidjan	-1,505
Jeddah	1,214		Riga	-1,396
Bangkok	1,194		Calcutta	-1,254
Edinburgh	1,179		Warsaw	-1,252
Munich	1,150		Doula	-1,248
Medellin	1,109		Ljubljana	-1,228
Vancouver	1,082		Dar Es Salaam	-1,212
Santo Domingo	1,070		Tallinn	-1,196
Bordeaux	1,033		Bristol	-1,195
Edmonton	1,019		Jakarta	-1,166
Basel	1,016		Lagos	-1,130
Durban	1,012		Prague	-1,121

			Guangzhou	-1,113
			Sofia	-1,103
			Kiev	-1,081
			Vilnius	-1,050
			Hanoi	-1,038
			Accra	-1,020
			Moscow	-1,014
			Leeds	-1,008

Table 5: Leading Non-US world cities, North and South.

Global North		
City	Residual	Serviced or visited reason?
Paris	1,302	over-visited
London	0,942	over-visited
Madrid	0,531	over-visited
Toronto	0,528	over-visited
Amsterdam	0,479	good fit
Milan	0,443	good fit
Hong Kong	0,336	good fit
Singapore	0,228	good fit
Sydney	0,061	good fit
Tokyo	-0,328	over-serviced
Global South		
City	Residual	Serviced or visited reason?
Bangkok	1,196	over-visited
Mexico City	0,679	over-visited
Johannesburg	0,341	good fit
Sao Paulo	0,281	good fit
Mumbai	0,142	good fit
Buenos Aires	0,042	good fit
Kuala Lumpur	-0,117	over-serviced
Beijing	-0,676	over-serviced
Shanghai	-0,702	over-serviced
Jakarta	-1,130	over-serviced

FIGURES

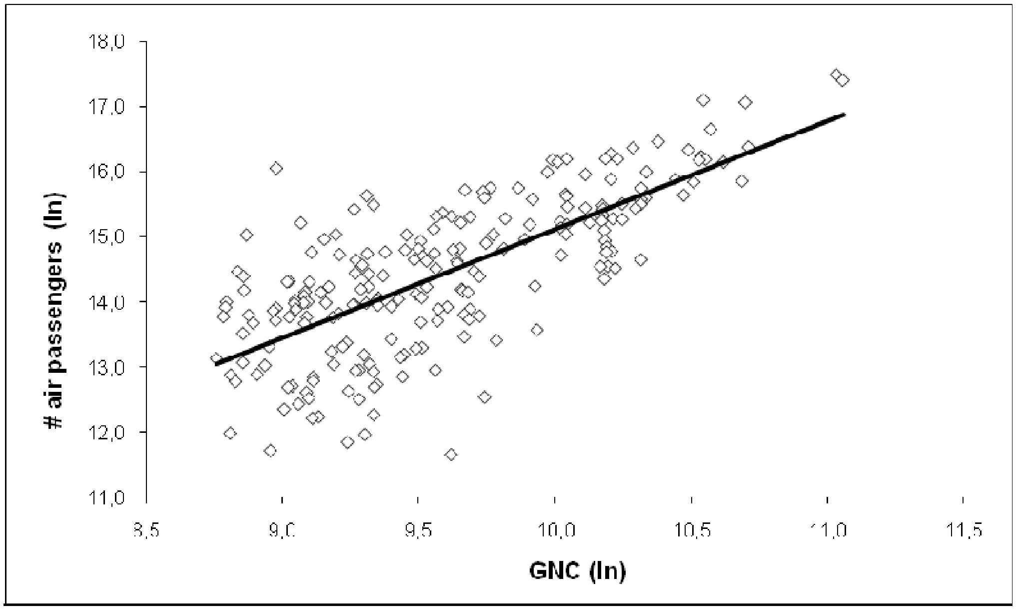

Figure 1: Regression analysis for 214 cities

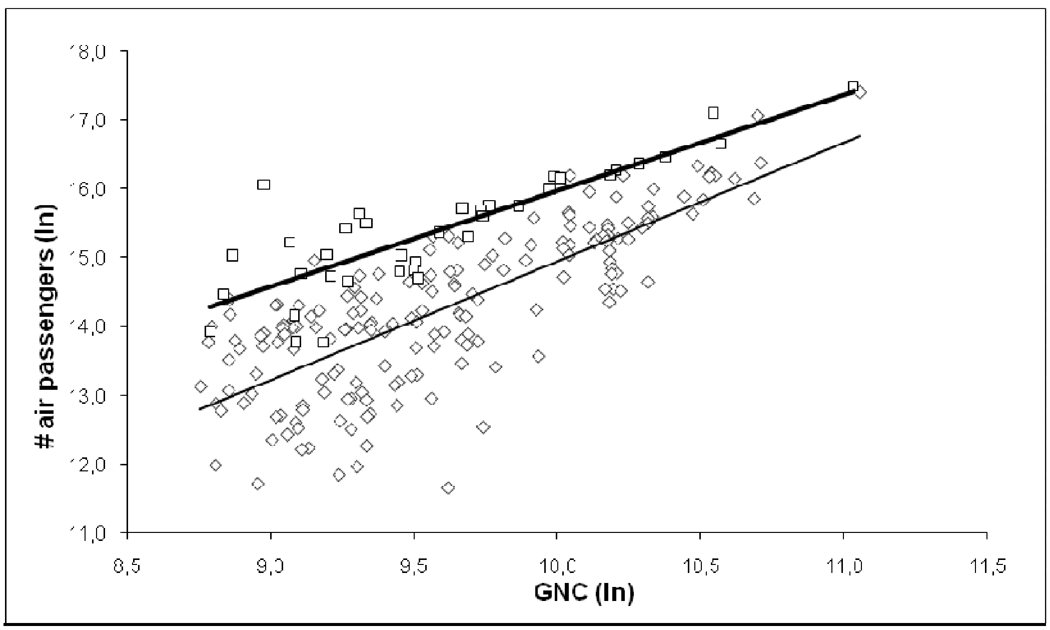

Figure 2: The two models

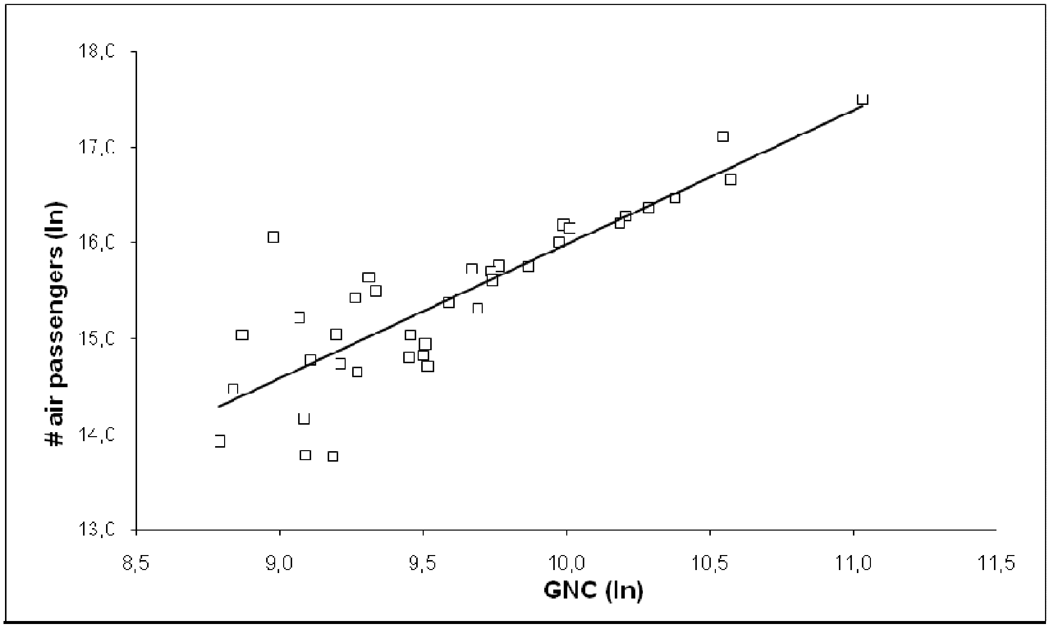

Figure 3: Regression analysis for US cities (model 1)

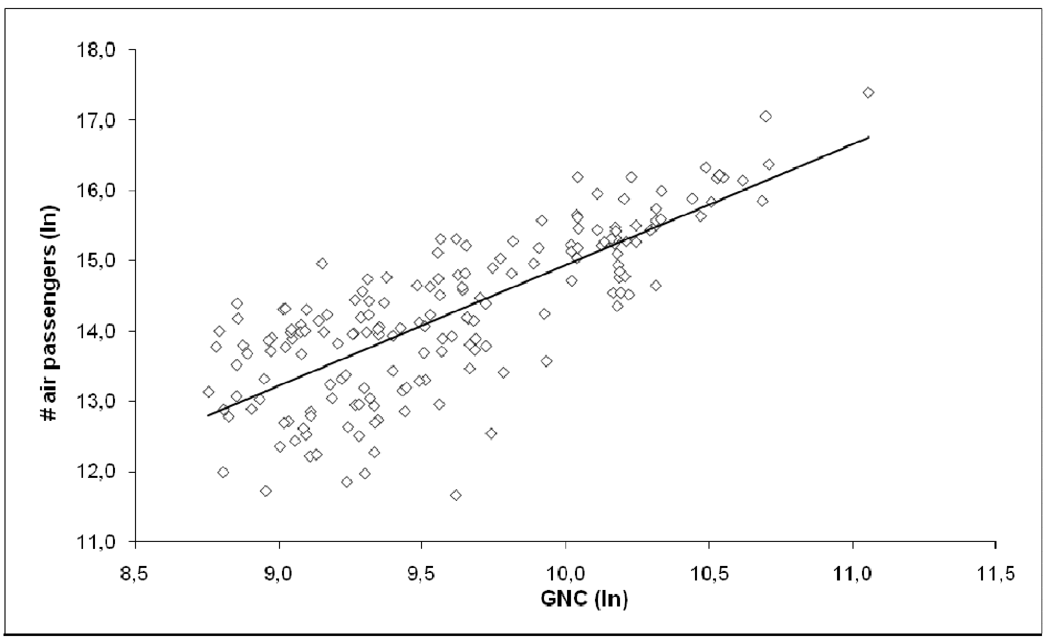

Figure 4: Regression analysis for non-US cities (model 2)